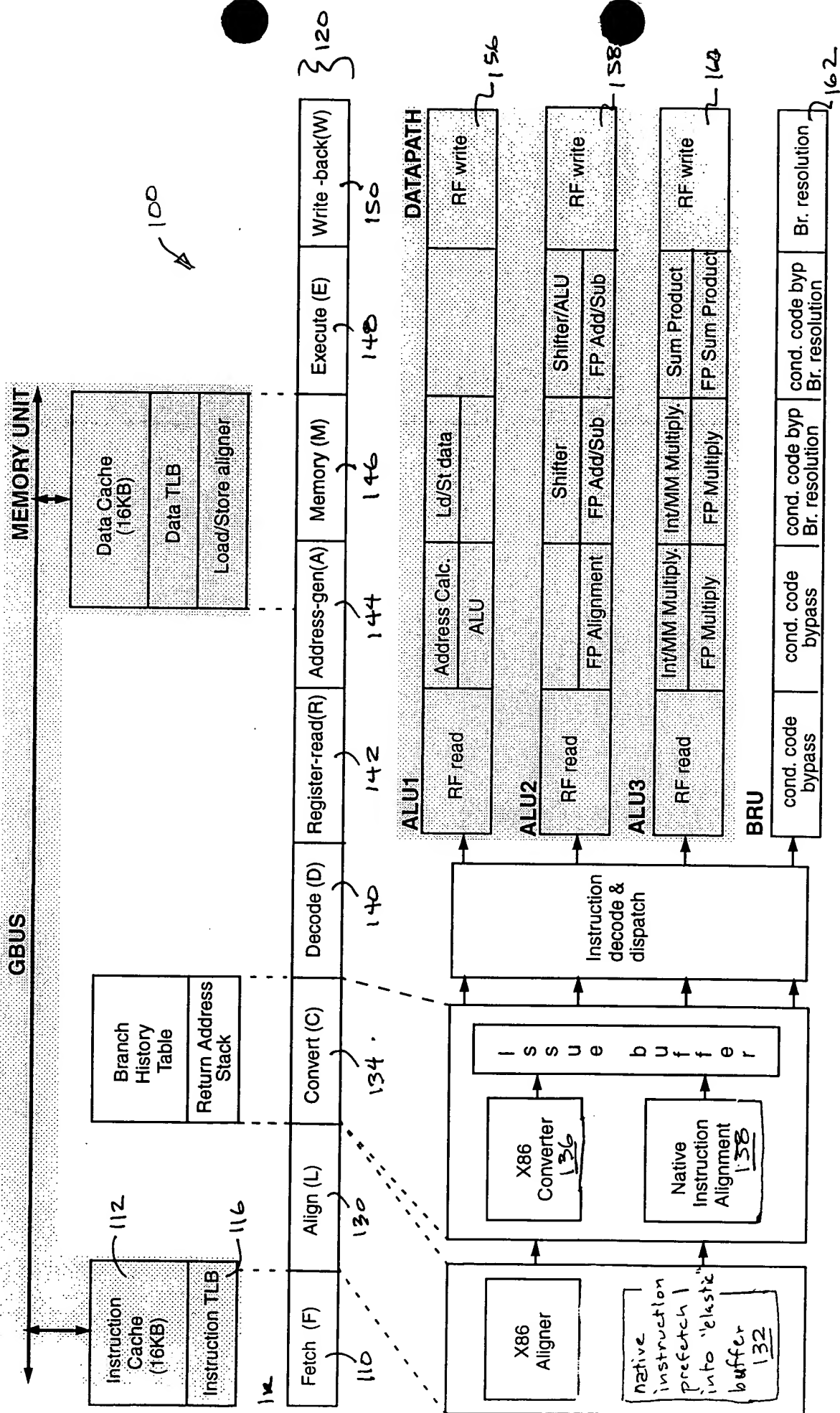


Fig. 1a

Fig. 1b



The diagram illustrates the memory mapping process in an x86 architecture. It shows the flow from a Logical Address (segment and offset) through x86 segment translation to a Linear Address or Virtual Address. This address is then mapped to physical memory via the Page Directory, Page Table, and PFAT (Physical Frame Address Table). The TLB (Translation Lookaside Buffer) is also shown, which caches recent translations. The final output is the Physical Memory address.

Logical Address

segment | offset

x86 segment translation

Linear Address or Virtual Address

170

Page Directory

Page Table

PFAT 172

174

176

176

118

TLB

Physical Memory

ISA 180

XP 186

FAR CALL

Near Call

Near Jump

Cond Jump

JNZ

6 5 4 3 2 1 0

Fig. 10 - Memory Mapping

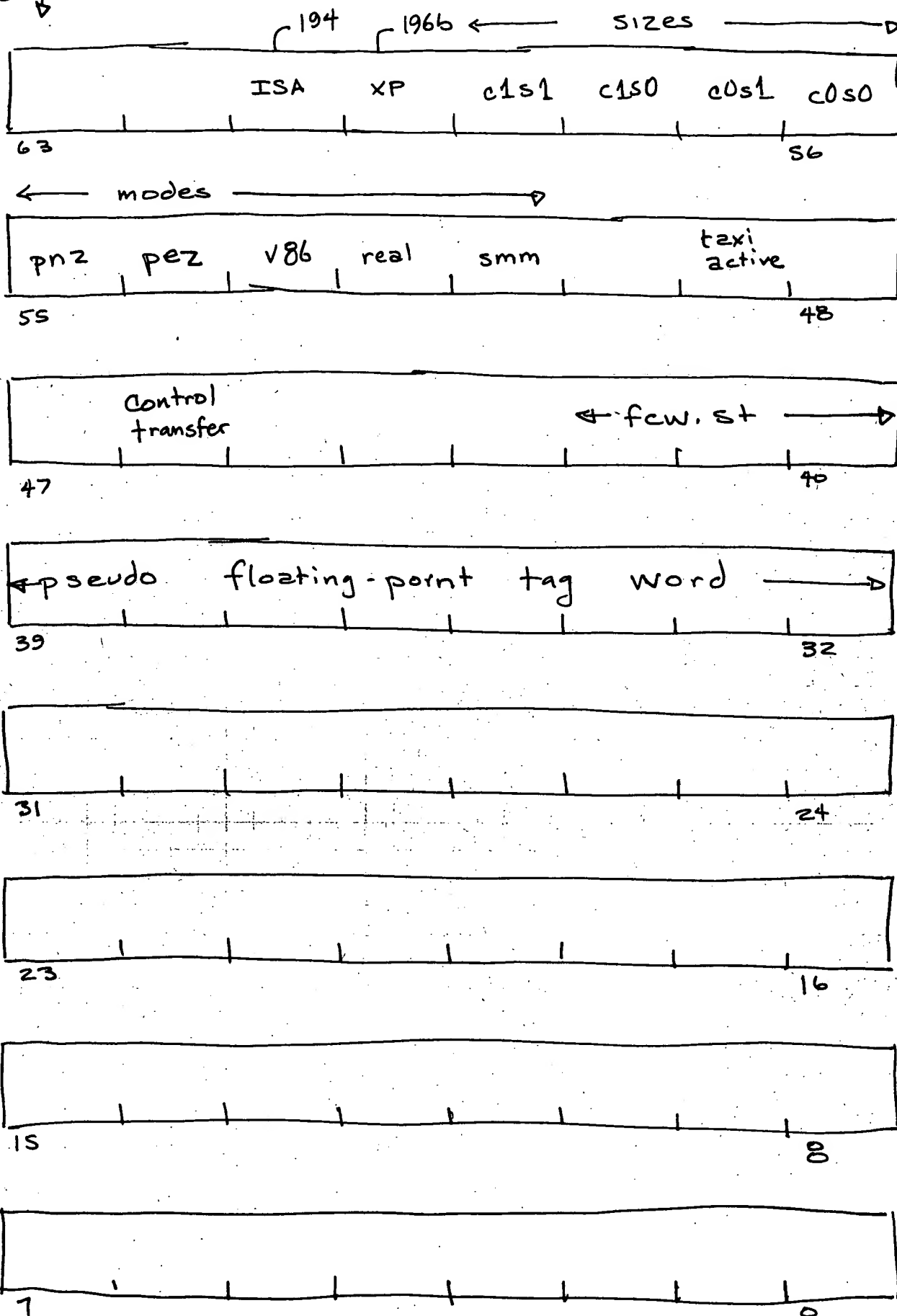


Fig. 1d

I-TLB property bits	Decoded property values			Interpretation	Instructions sent to:	Collect profile trace-packets?	Probe for translated code	I/O memory reference exceptions
	ISA 194	CC 200	Protected					
00	Tap	Tap	no	Native code observing native RISCy calling conventions	Native decoder	No	No	Fault if SEG.tio
01	Tap	x86	no	Native code observing x86 calling conventions	Native decoder	No	No	Fault if SEG.tio
10	x86	x86	no	x86 code, unprotected - TAX! profile collection only	x86 HW converter	If enabled	No	Trap if profiling
11	x86	x86	yes	x86 code, protected - TAX! code may be available	x86 HW converter	If enabled	Based on I-TLB probe attributes	Trap if profiling

Fig. 2a Significance of the I-TLB property bits

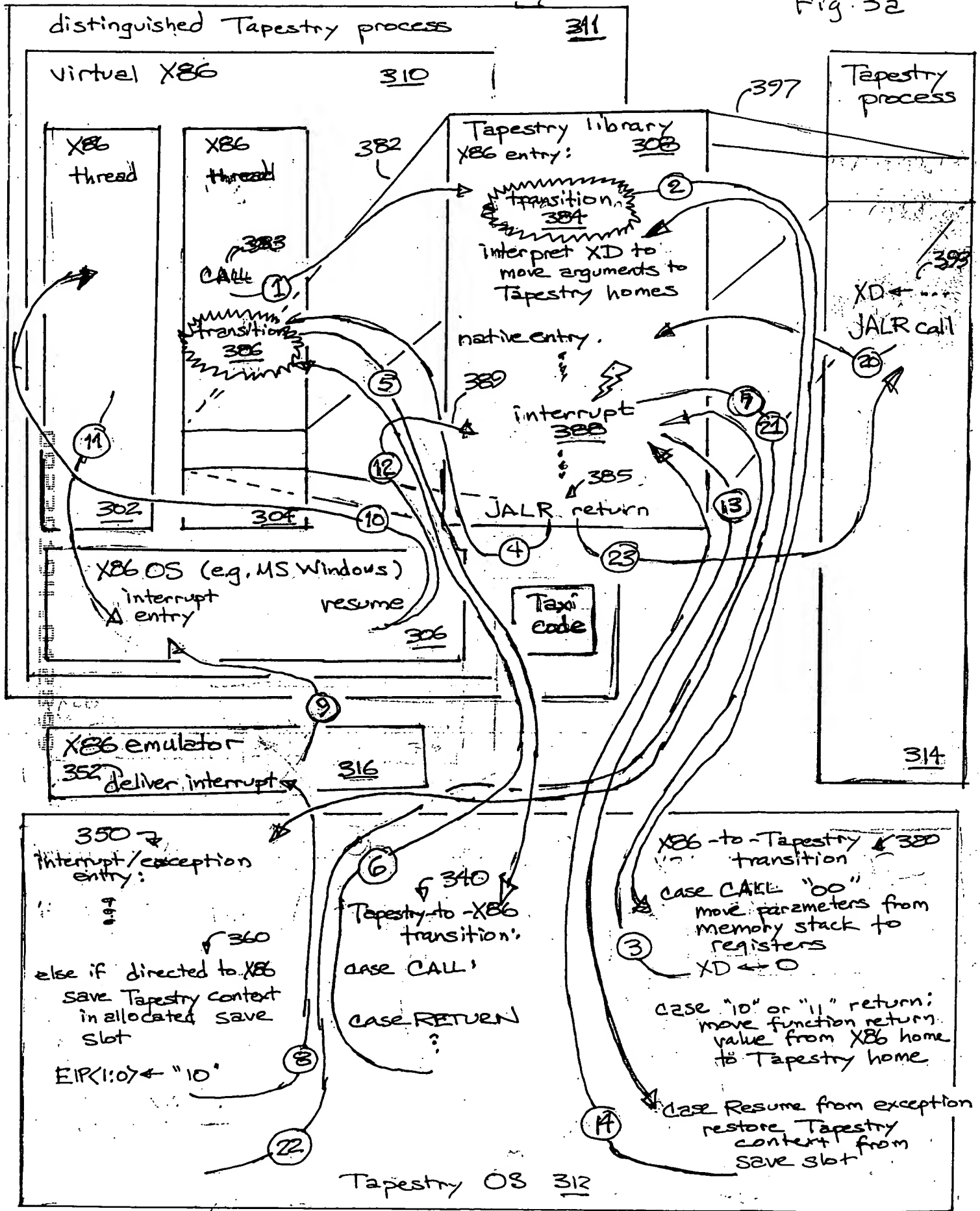
Transition (source => dest) ISA & CC property values	Handler Action
00 => 00	No transition exception
00 => 01	VECT_xxx_X86_CC exception - handler converts from native to x86 conventions
00 => 1x	VECT_xxx_X86_CC exception - handler converts from native to x86 conventions, sets up expected emulator and profiling state
01 => 00	VECT_xxx_TAP_CC exception - handler converts from x86 to native conventions
01 => 01	No transition exception
01 => 1x	VECT_X86_ISA exception [conditional based on PCW.X86_ISA_ENABLE flag] - sets up expected emulator and profiling state
1x => 00	VECT_xxx_TAP_CC exception - handler converts from x86 to native conventions
1x => 01	VECT_TAP_ISA exception [conditional based PCW.TAP_ISA_ENABLE flag] - no convention conversion necessary
1x => 10	No transition exception - [profile complete possible, probe possible]
1x => 11	No transition exception - [profile complete possible, probe NOT possible]

Fig. 2b ISA & CC transition exception flow

name	description	type
VECT_call_X86_CC	push args, return address, set up x86 state	fault on target instruction
VECT_jump_X86_CC	set up x86 state	fault on target instruction
VECT_ret_no_fp_X86_CC	return value to eax:edx, set up x86 state	fault on target instruction
VECT_ret_fp_X86_CC	return value to x86 fp stack, set up x86 state	fault on target instruction
VECT_call_TAP_CC	x86 stack args, return address to registers	fault on target instruction
VECT_jump_TAP_CC	x86 stack args to registers	fault on target instruction
VECT_ret_no_fp_TAP_CC	return value to RV0	fault on target instruction
VECT_ret_any_TAP_CC	return type unknown, setup RV0 and RVDV	fault on target instruction

Fig. 2c CC transition exceptions

Fig. 32



## Flat 32-bit "Near" Address Space

### Transparency:

- . x86 code adheres to traditional x86 stack-based conventions
- . RISC uses higher performance register-based conventions
- . Caller has no knowledge of callee's ISA
- . Callee has no knowledge of ISA to which it will return

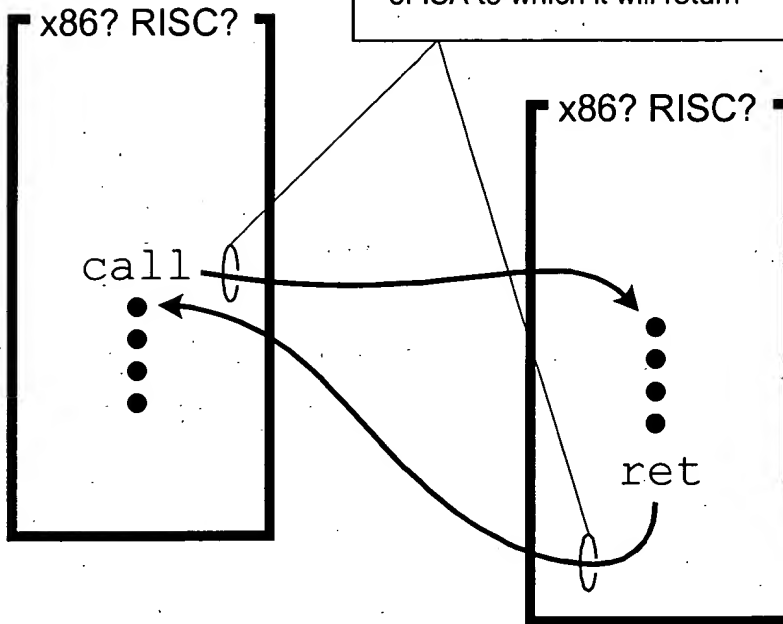
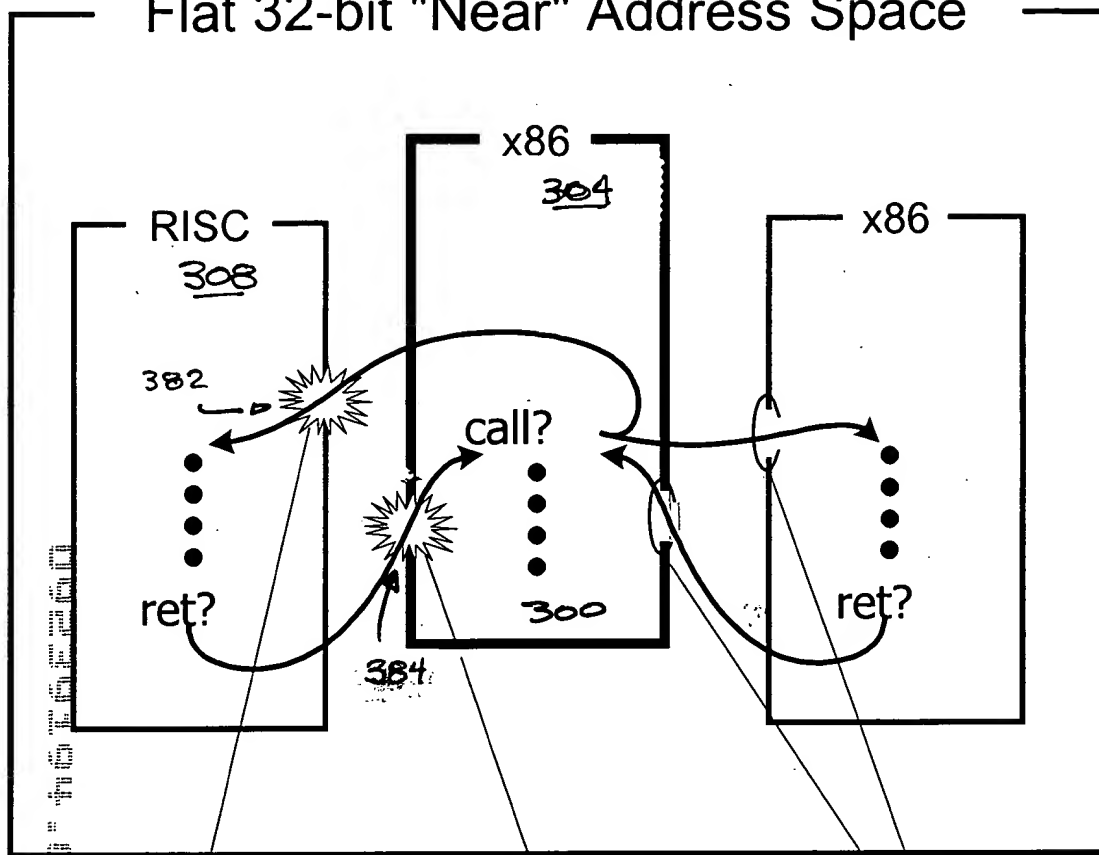


Fig. 3b

# Flat 32-bit "Near" Address Space



x86 → RISC transition:  
map x86 call to RISC

322 (Fig. 3h)

RISC → x86 transition:  
map x86 return to RISC

342 (Fig. 3i)

no ISA transition:  
no mapping required

Fig. 3c



# Flat 32-bit "Near" Address Space

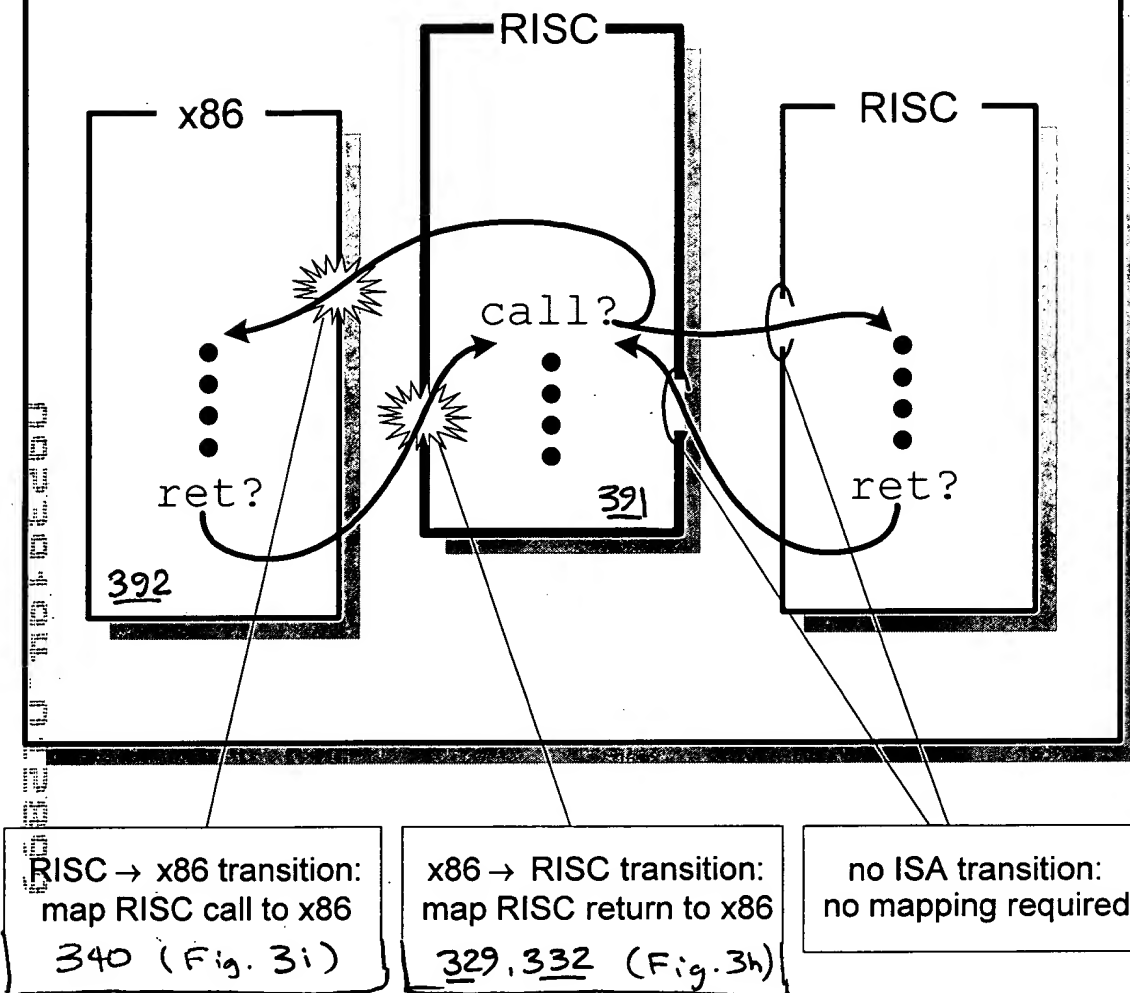
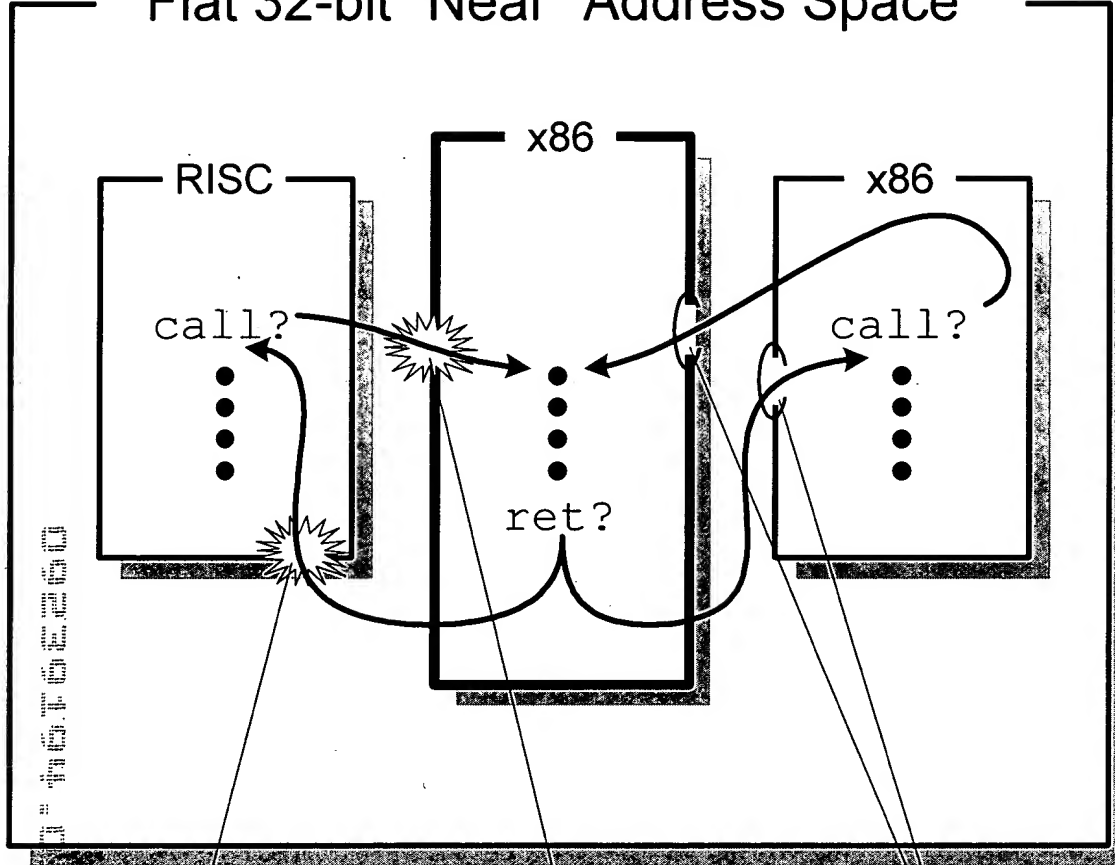


Fig. 3d

# Flat 32-bit "Near" Address Space



x86 → RISC transition:  
map RISC return to x86  
329, 332 (Fig. 3h)

RISC → x86 transition:  
map RISC call to x86  
343-348 (Fig. 3i)

no ISA transition:  
no mapping required

Fig. 3e

# Flat 32-bit "Near" Address Space

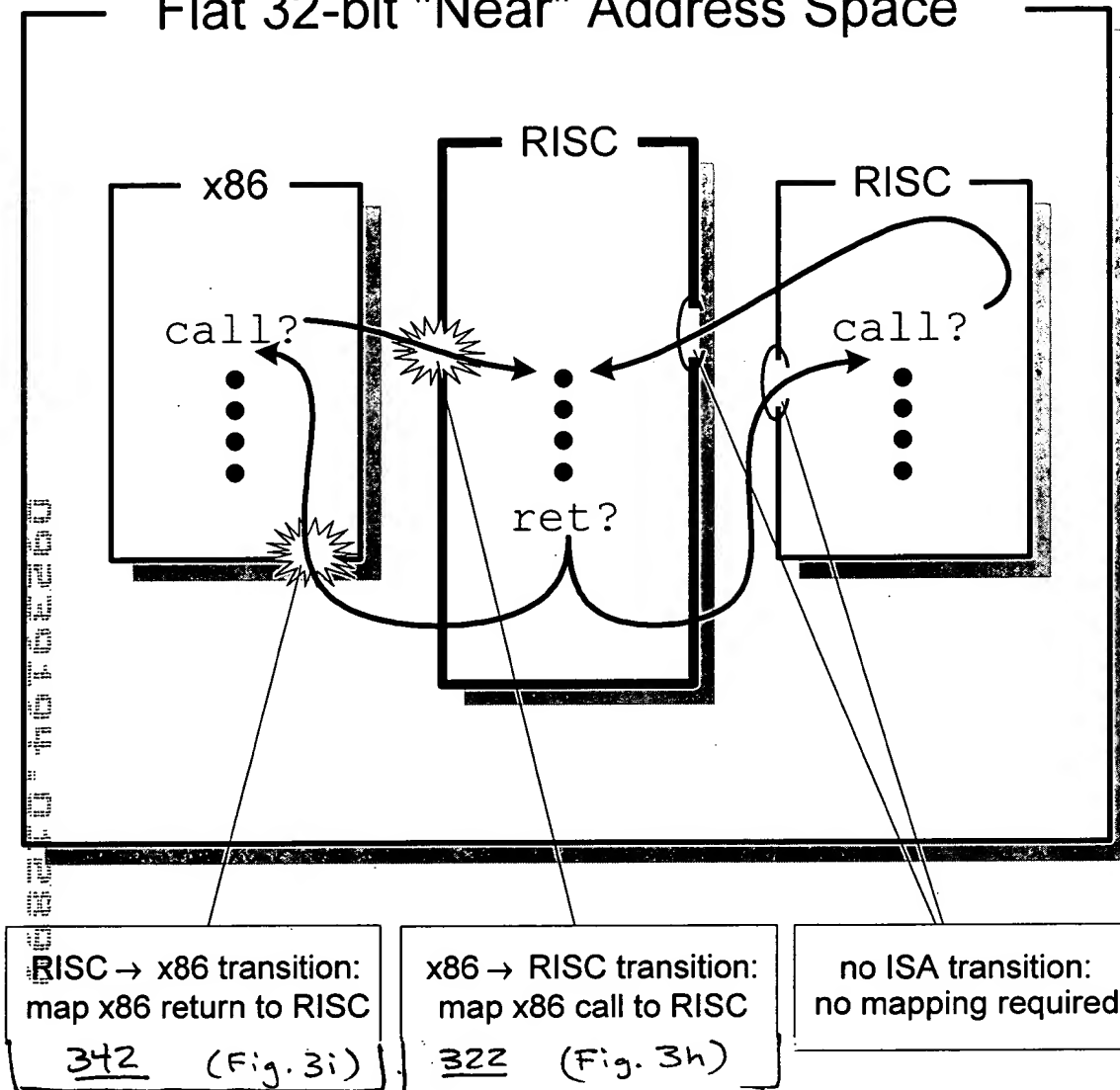


Fig. 3f

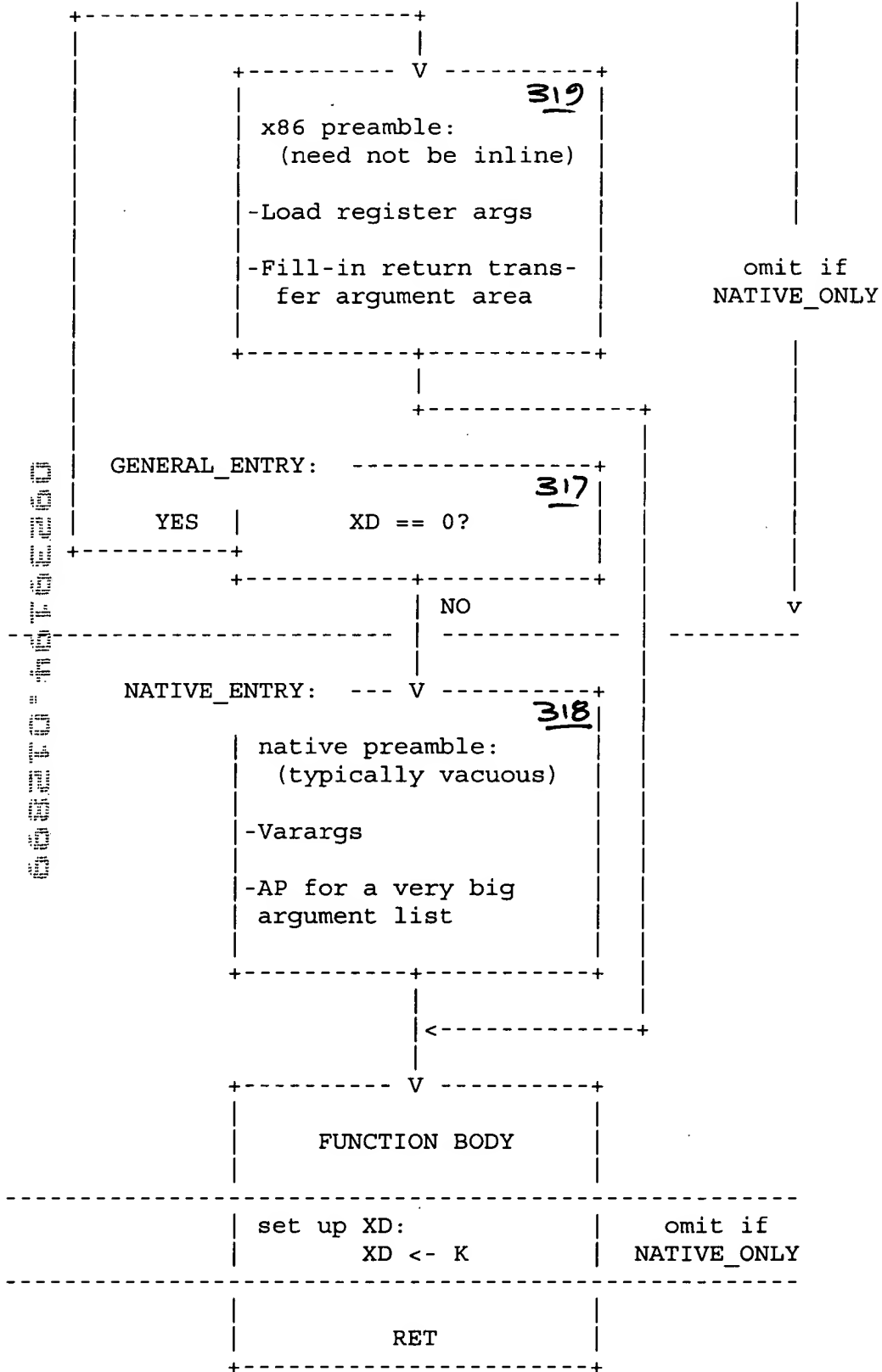


Fig. 3g

## X86-to-Tapestry transition exception handler

// This handler is entered under the following conditions:

- // 1. An x86 caller invokes a native function
- // 2. An x86 function returns to a native caller
- // 3. x86 software returns to or resumes an interrupted native function following
- // an external asynchronous interrupt, a processor exception, or a context switch

dispatch on the two least-significant bits of the destination address {

case "00" // calling a native subprogram

// copy linkage and stack frame information and call parameters from the memory  
// stack to the analogous Tapestry registers

LR ← [SP++] // set up linkage register ~ 323

AP ← SP // address of first argument ~ 324

SP ← SP - 8 // allocate return transfer argument area ~ 326

SP ← SP & (-32) // round the stack pointer down to a 0 mode 32 boundary ~ 327

XD ← 0 // inform callee that caller uses X86 calling conventions ~ 328

case "01" // resuming an X86 thread suspended during execution of a native routine

if the redundant copies of the save slot number in EAX and EDX do not match or if  
the redundant copies of the timestamp in EBX:ECX and ESI:EDI do not match { ~ 371

// some form of bug or thread corruption has been detected

goto TAPESTRY\_CRASH\_SYSTEM( thread-corruption-error-code ) ~ 372

}  
save the EBX:ECX timestamp in a 64-bit exception handler temporary register  
(this will not be overwritten during restoration of the full native context) ~ 373

use save slot number in EAX to locate actual save slot storage ~ 374

restore full entire native context (includes new values for all x86 registers) ~ 375

if save slot's timestamp does not match the saved timestamp { ~ 376

// save slot as been reallocated; save slot exhaustion has been detected

goto TAPESTRY\_CRASH\_SYSTEM( save-slot-overwritten-error-code ) ~ 377

}

free the save slot ~ 378

case "10" // returning from X86 callee to native caller, result already in registers

RV0<63:32> ← edx<31:00> // in case result is 64 bits ~ 333

convert the FP top-of-stack value from 80 bit X86 form to 64-bit form in RVDP ~ 334

SP ← ESI // restore SP from time of call ~ 337

case "11" // returning from X86 callee to native caller, load large result from memory

RV0..RV3 ← load 32 bytes from [ESI-32] // (guaranteed naturally aligned) ~ 330

SP ← ESI // restore SP from time of call ~ 337

}

EPC ← EPC & -4 // reset the two low-order bits to zero ~ 336

RFE ~ 338

Fig. 3h

## Tapestry-to-X86 transition exception handler

// This handler is entered under the following conditions:

- // 1. a native caller invokes an x86 function
- // 2. a native function returns to an x86 caller

switch on XD<3:0> { ~ 341

XD\_RET\_FP: // result type is floating point  
 F0/F1 ← FINFLATE.de( RVDP ) // X86 FP results are 80 bits  
 SP ← from RXA save // discard RXA, pad, args  
 FPCW ← image after FINIT & push // FP stack has 1 entry  
 goto EXIT

XD\_RET\_WRITEBACK: // store result to @RVA, leave RVA in eax  
 RVA ← from RXA save // address of result area  
 copy decode(XD<8:4>) bytes from RV0..RV3 to [RVA]  
 eax ← RVA // X86 expects RVA in eax  
 SP ← from RXA save // discard RXA, pad, args  
 FPCW ← image after FINIT // FP stack is empty  
 goto EXIT

XD\_RET\_SCALAR: // result in eax:edx  
 edx<31:00> ← eax<63:32> // in case result is 64 bits  
 SP ← from RXA save // discard RXA, pad, args  
 FPCW ← image after FINIT // FP stack is empty  
 goto EXIT

XD\_CALL\_HIDDEN\_TEMP: // allocate 32 byte aligned hidden temp  
 esi ← SP // stack cut back on return ~ 343  
 SP ← SP - 32 // allocate max size temp } 344  
 RVA ← SP // RVA consumed later by RR  
 LR<1:0> ← "11" // flag address for return & reload ~ 345  
 goto CALL\_COMMON

default: // remaining XD\_CALL\_xxx encodings  
 esi ← SP // stack cut back on return ~ 343  
 LR<1:0> ← "10" // flag address for return ~ 346

CALL\_COMMON:  
 interpret XD to push and/or reposition args ~ 347  
 [--SP] ← LR // push LR as return address

EXIT:  
 setup emulator context and profiling ring buffer pointer

}  
 RFE ~ 349 // to original target

Fig. 3i

### interrupt/exception handler of Tapestry operating system:

// Control vectors here when a synchronous exception or asynchronous interrupt is to be  
// exported to / manifested in an x86 machine.

// The interrupt is directed to something within the virtual X86, and thus there is a possibility  
// that the X86 operating system will context switch. So we need to distinguish two cases:

// either the running process has only X86 state that is relevant to save, or

// there is extended state that must be saved and associated with the current machine context

// (e.g., extended state in a Tapestry library call in behalf of a process managed by X86 OS)

if execution was interrupted in the converter – EPC.ISA == X86 {

// no dependence on extended/native state possible hence no need to save any

goto EM86\_Deliver\_Interrupt( interrupt-byte )

} else if EPC.Taxi\_Active {

// A Taxi translated version of some X86 code was running. Taxi will rollback to an

// x86 instruction boundary. Then, if the rollback was induced by an asynchronous external

// interrupt Taxi will deliver the appropriate x86 interrupt. Else, the rollback was induced

// by a synchronous event so Taxi will resume execution in the converter, retriggering the

// exception but this time will EPC.ISA == X86

goto TAXi\_Rollback( asynchronous-flag, interrupt-byte )

} else if EPC.EM86 {

// The emulator has been interrupted. In theory the emulator is coded to allow for such

// conditions and permits re-entry during long running routines (e.g. far call through a gate)

// to deliver external interrupts

goto EM86\_Deliver\_Interrupt( interrupt-byte )

} else {

// This is the most difficult case – the machine was executing native Tapestry code on

// behalf of an X86 thread. The X86 operating system may context switch. We must save

// all native state and be able to locate it again when the x86 thread is resumed.

allocate a free save slot; if unavailable free the save slot with oldest timestamp and try again  
save the entire native state (both the X86 and the extended state)

save the X86 EIP in the save slot

overwrite the two low-order bits of EPC with “01” (will become X86 interrupt EIP)

store the 64-bit timestamp in the save slot, in the X86 EBX:ECX register pair (and,  
for further security, store a redundant copy in the X86 ESI:EDI register pair)

store the a number of the allocated save slot in the X86 EAX register (and, again for  
further security, store a redundant copy in the X86 EDX register)

goto EM86\_Deliver\_Interrupt( interrupt-byte )

}

350

351

353

354

360

Fig. 3j

350

```

typedef struct {
    save_slot_t * newer;           // pointer to next-most-recently-allocated save slot } 379c
    save_slot_t * older;          // pointer to next-older save slot
    unsigned int64 epc;            // saved exception PC/IP
    unsigned int64 pcw;            // saved exception PCW (program control word) } 356
    unsigned int64 registers[63]; // save the 63 writeable general registers
    ...                          // other words of Tapestry context
    timestamp_t timestamp;         // timestamp to detect buffer overrun ~ 358
    int save_slot_ID;              // ID number of the save slot ~ 357
    boolean save_slot_is_full;     // full / empty flag ~ 359
} save_slot_t;

```

355

```

save_slot_t * save_slot_head;    // pointer to the head of the queue ~ 379a
save_slot_t * save_slot_tail;    // pointer to the tail of the queue ~ 379b

```

### system initialization

reserve several pages of unpagged memory for save slots

Fig. 3k



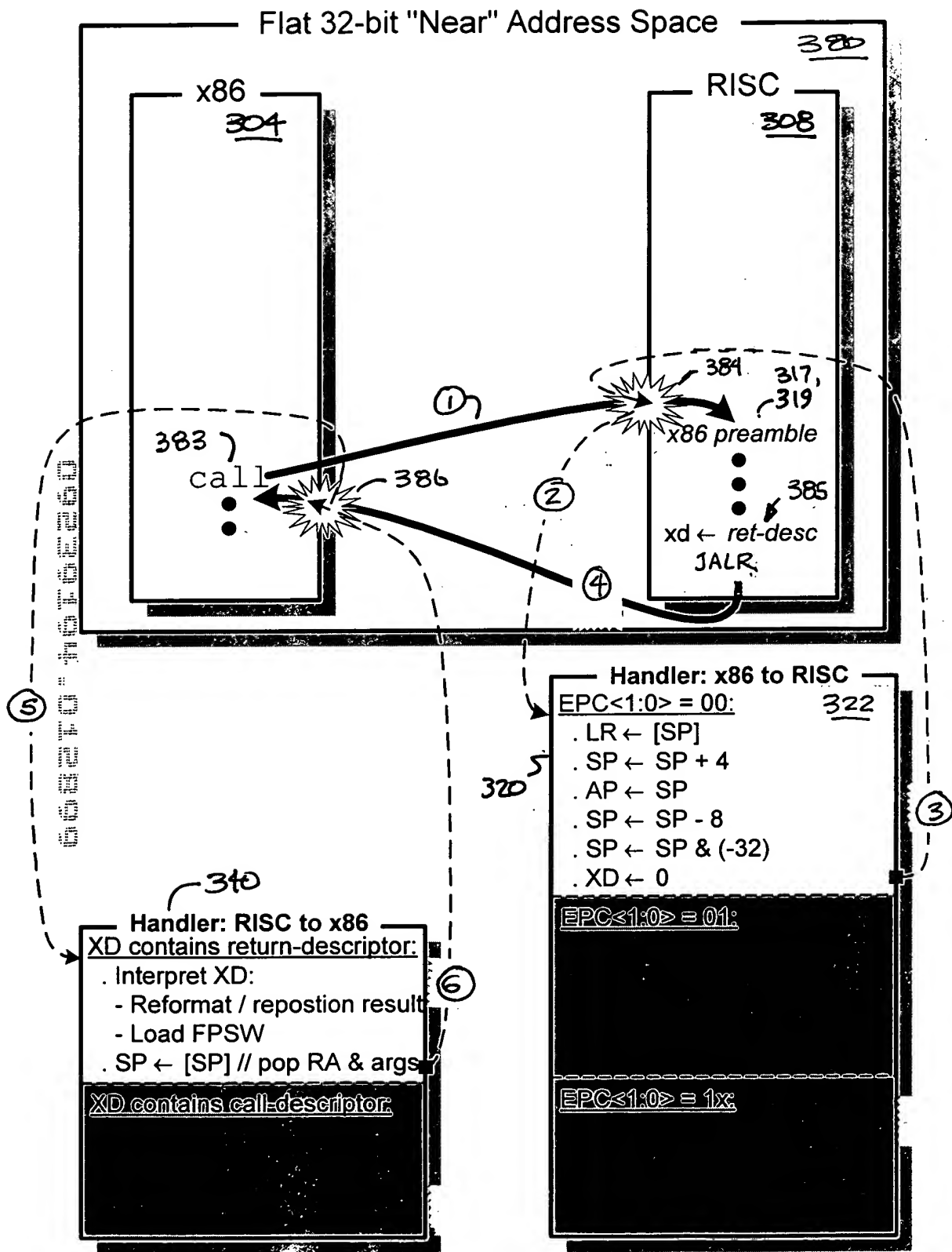


Fig. 31

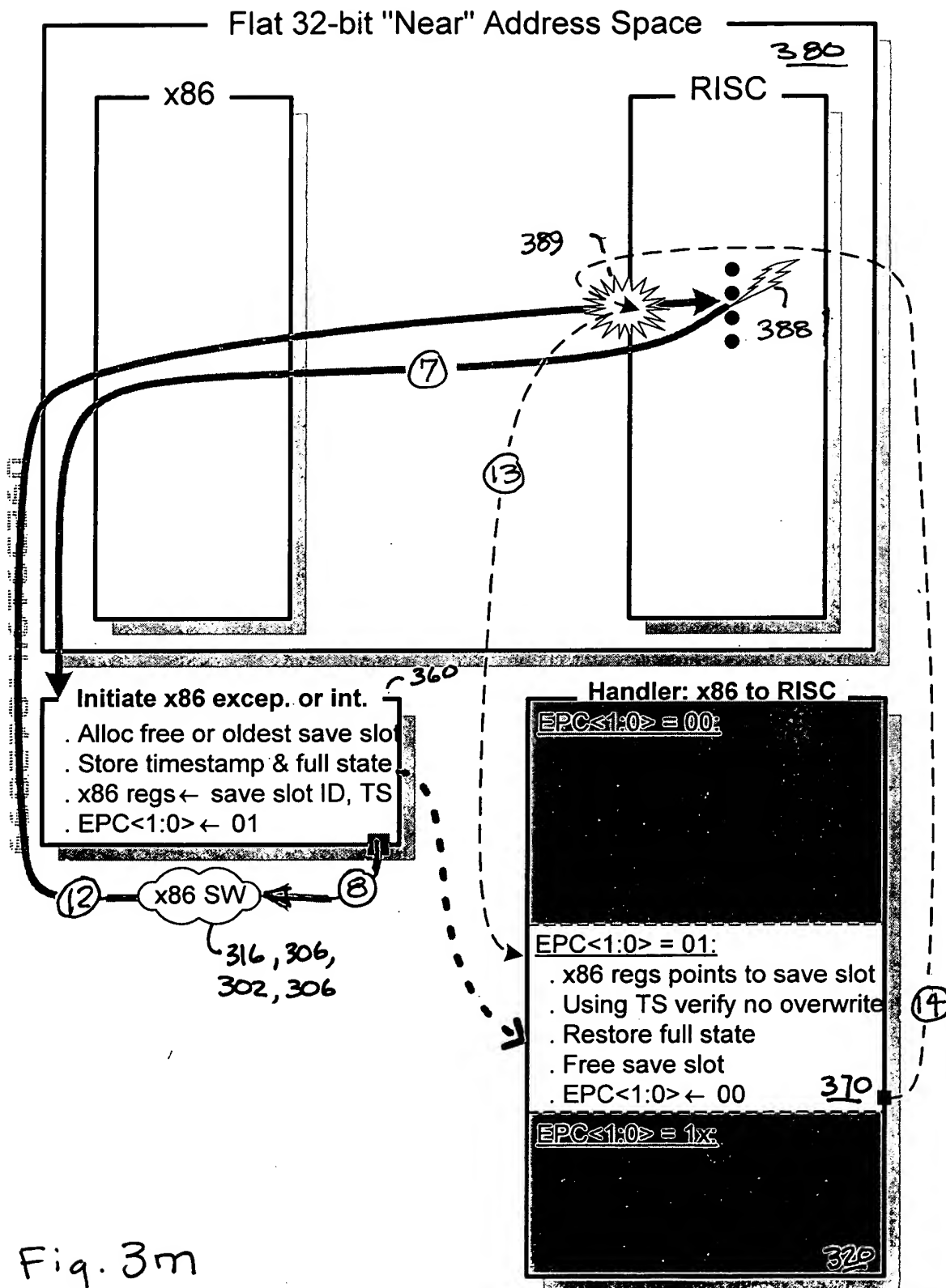


Fig. 3m

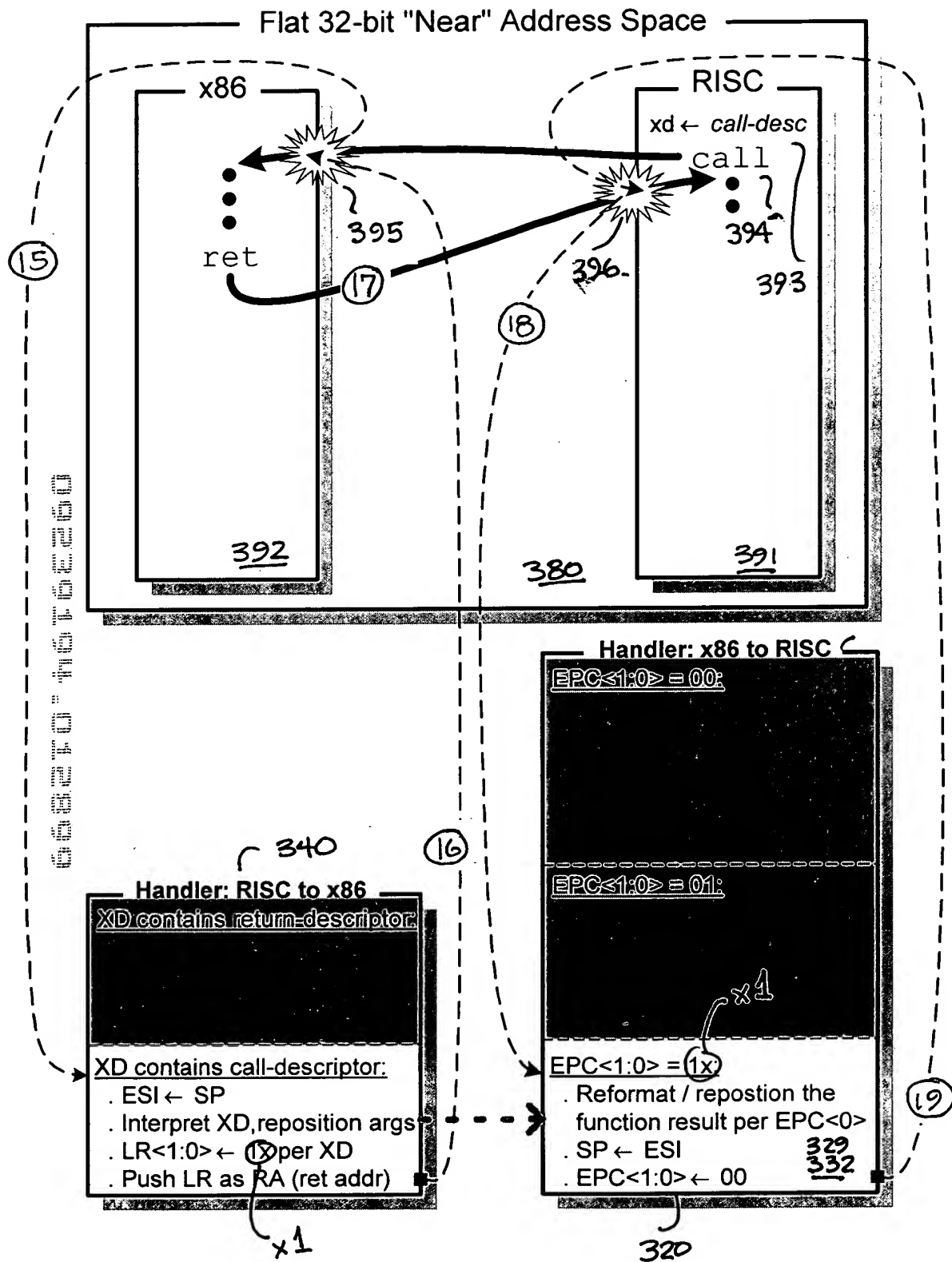
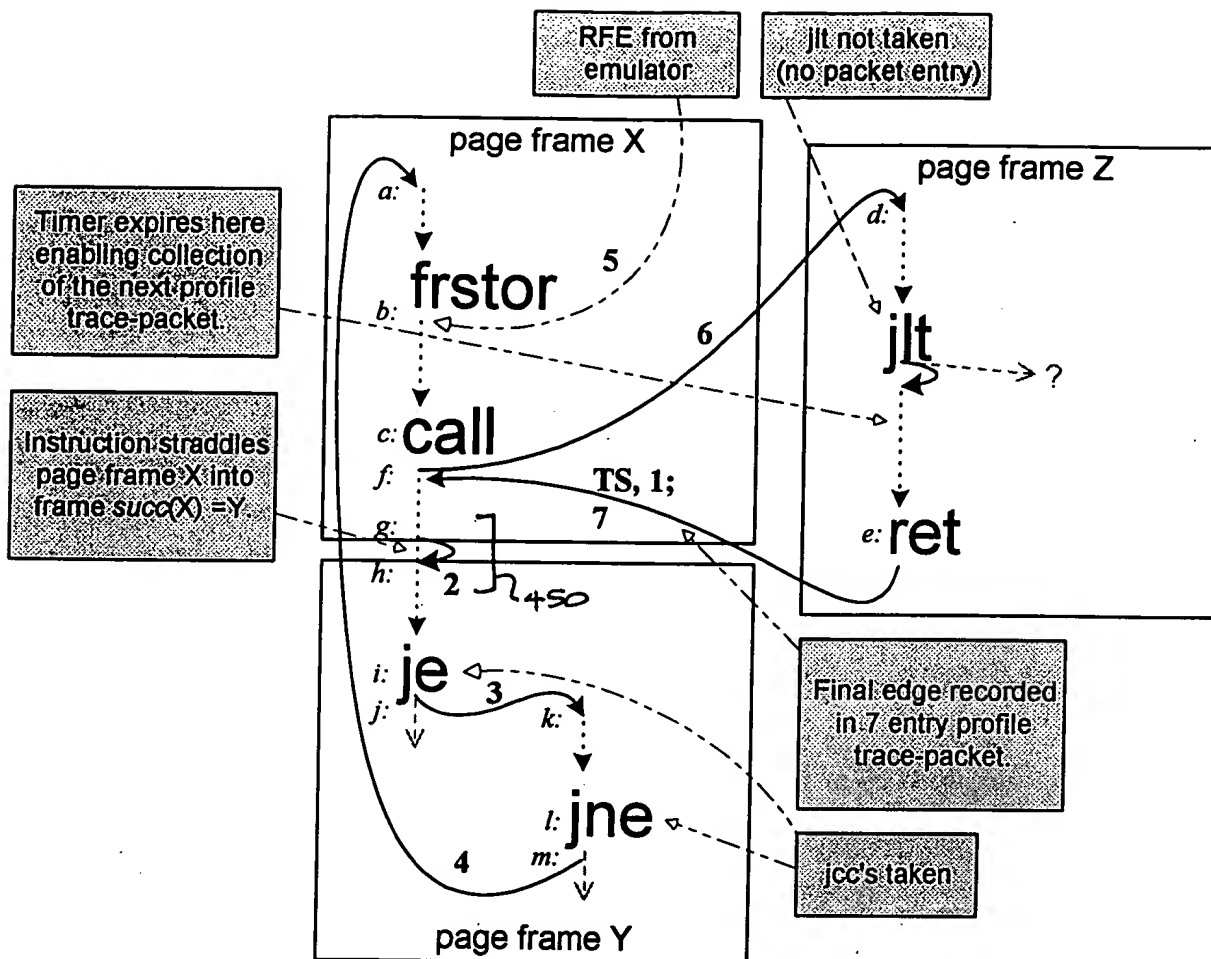


Fig. 3n

[illegible]

## 7 entry trace packet

Entry	Event Code	Done Addr	Next Addr
	64 bit time stamp		
1	ret	x86 context	<i>phys X:f</i>
2	new page	<i>phys Y:g</i>	<i>phys Y:h</i>
3	jcc forward	<i>phys Y:i</i>	<i>phys Y:k</i>
4	jnz backward	<i>phys Y:l</i>	<i>phys X:a</i>
5	seq; env change	x86 context	<i>phys X:b</i>
6	ip-rel near call	<i>phys X:c</i>	<i>phys Z:d</i>
7	near ret	<i>phys Z:e</i>	<i>phys X:f</i>

Fig. 4a

Source	Code	Event	Reuse event code	Profileable event	Initiate packet	Probeable event	Probe event bit - ITLB probe attribute or Emulator probe
RFE (Context at Point entry)	0.0000	Default (x86 transparent) event, reuse all converter values	yes	no no no no reuse event code	no no no no	no no no no	-
	0.0001	Simple x86 instruction completion (reuse event code)	yes				
	0.0010	Probe exception failed	yes				
	0.0011	Probe exception failed, reload probe timer	yes				
	0.0100	flush event	no	no	no	no	-
	0.0101	Sequential; execution environment changed - force event	no	yes	no	no	-
	0.0110	Far RET	no	yes	yes	no	-
	0.0111	IRET	no	yes	no	no	-
	0.1000	Far CALL	no	yes	yes	yes	Far call
	0.1001	Far JMP	no	yes	yes	no	-
	0.1010	Special; emulator execution, supply extra instruction data <sup>a</sup>	no	yes	no	no	-
	0.1011	Abort profile collection	no	no	no	no	-
	0.1100	x86 synchronous/asynchronous interrupt w/probe (GRP 0)	no	yes	yes	yes	Emulator probe
	0.1101	x86 synchronous/asynchronous interrupt (GRP 0)	no	yes	yes	no	-
	0.1110	x86 synchronous/asynchronous interrupt w/probe (GRP 1)	no	yes	yes	yes	Emulator probe
	0.1111	x86 synchronous/asynchronous interrupt (GRP 1)	no	yes	yes	no	-
Converter (Near_Edge entry)	1.0000	IP-relative JNZ forward (opcode: 75, 0F 85)	no	yes	yes	no	-
	1.0001	IP-relative JNZ backward (opcode: 75, 0F 85)	no	yes	yes	yes	Jnz
	1.0010	IP-relative conditional jump forward - (Jcc, Jcxz, loop)	no	yes	yes	no	-
	1.0011	IP-relative conditional jump backward - (Jcc, Jcxz, loop)	no	yes	yes	yes	Cond jump
	1.0100	IP-relative, near JMP forward (opcode: E9, EB)	no	yes	yes	no	-
	1.0101	IP-relative, near JMP backward (opcode: E9, EB)	no	yes	yes	yes	Near jump
	1.0110	RET/ RET imm16 (opcode C3, C2 /w)	no	yes	yes	no	-
	1.0111	IP-relative, near CALL (opcode: E8)	no	yes	yes	yes	Near call
	1.1000	REPE/REPNE CMPS/SCAS (opcode: A6, A7, AE, AF)	no	yes	no	no	-
	1.1001	REP MOVS/STOS/LDOS (opcode: A4, A5, AA, AB, AC, AD)	no	yes	no	no	-
	1.1010	Indirect near JMP (opcode: FF /4)	no	yes	yes	no	-
	1.1011	Indirect near CALL (opcode: FF /2)	no	yes	yes	yes	Near call
	1.1100	load from I/O memory (TLB.asi != 0) { not used in T1 }	no	yes	no	no	-
	1.1101	available for expansion	no	no	no	no	-
	1.1110	Default converter event; sequential	no	no	no	no	-
	1.1111	New page (instruction ends on last byte of a page frame or straddles across a page frame boundary)	no	yes	no	no	-

a. Used by emulator for new x86 opcodes. Extra information supplied in *Taxi\_Control.special\_opcode* bits.

Fig. 4b



**E** **A** **R** **C**

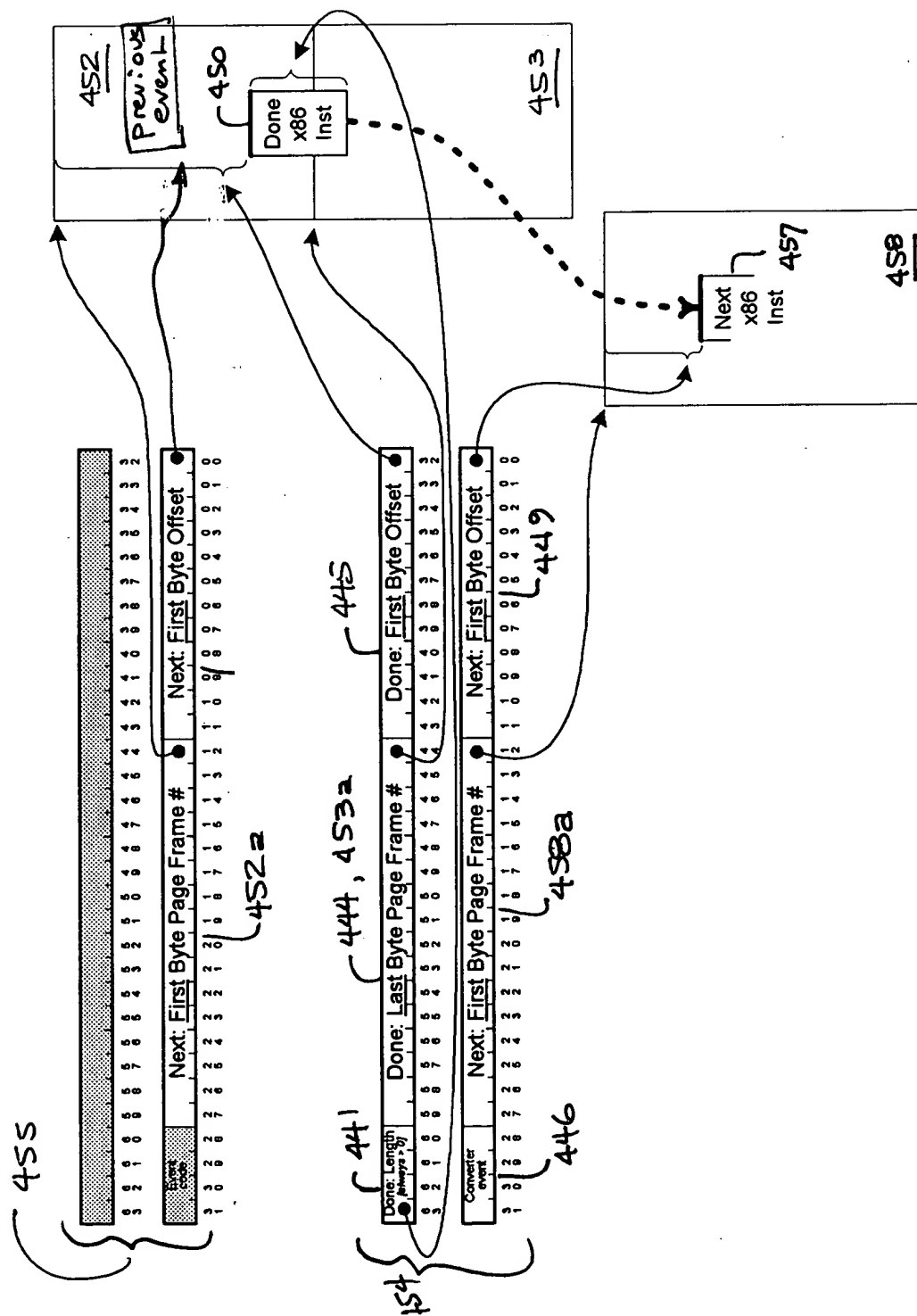


Fig. 4e





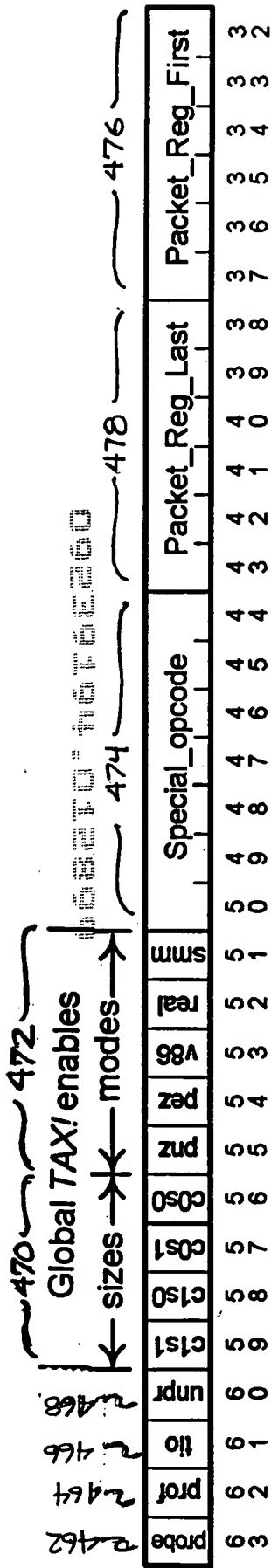


Fig. 48 Taxi\_Control processor register 460

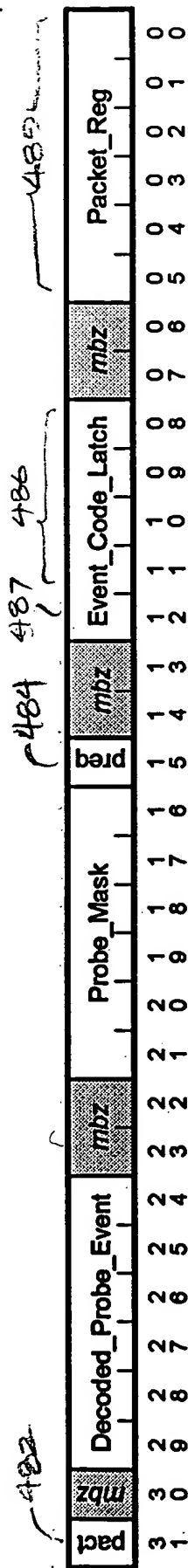


Fig. 4h

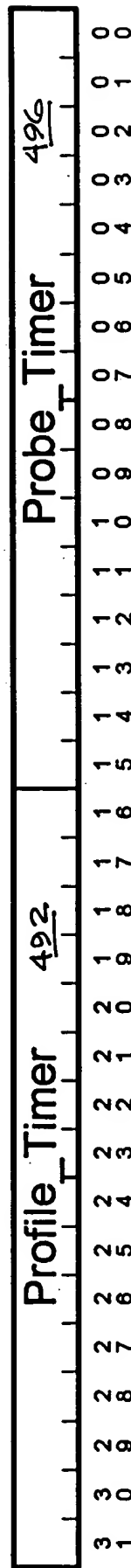


Fig. 4i Taxi\_Timers processor register

# Events

$pe_{init}$  = "initiate packet" profile event 418  
 $pe_{\overline{init}}$  = non-"initiate packet" profile event 416  
 $pe$  = any profile event 416  
 $te$  = timer expiry  
 $ap$  = abort packet

# State Variables

$PR$  = Profile\_Request flag 484  
 $PA$  = Profile\_Active flag 482

# Rules

$te$  event  $\Rightarrow$   
 $PR \leftarrow 1$   
 $PR \& \overline{PA} \& pe_{init} \Rightarrow$   
 $PR \leftarrow 0$   
 $PA \leftarrow 1$   
 Init Packet\_Reg  
 Save timestamp  
 Log event (CAP)  
 Full packet? / Packet\_Reg++  
 $PA \& pe \Rightarrow$   
 Log event (CAP or NE)  
 Full packet? / Packet\_Reg++  
 full packet  $\Rightarrow$   
 $PA \leftarrow 0$   
 Profile exception  
 $ap$  event  $\Rightarrow$   
 $PA \leftarrow 0$

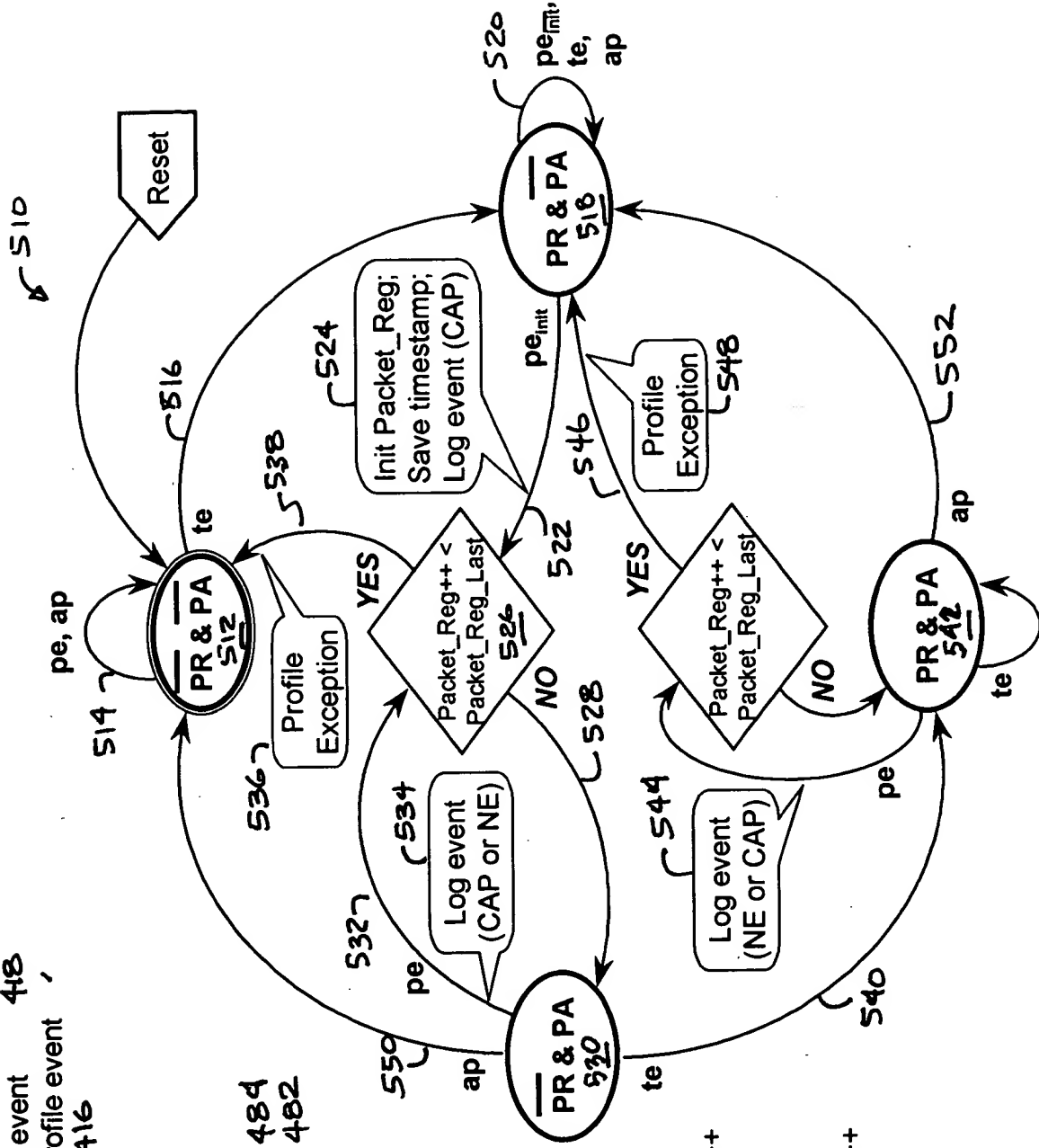


Fig. 5a

# taxi profile entry generation

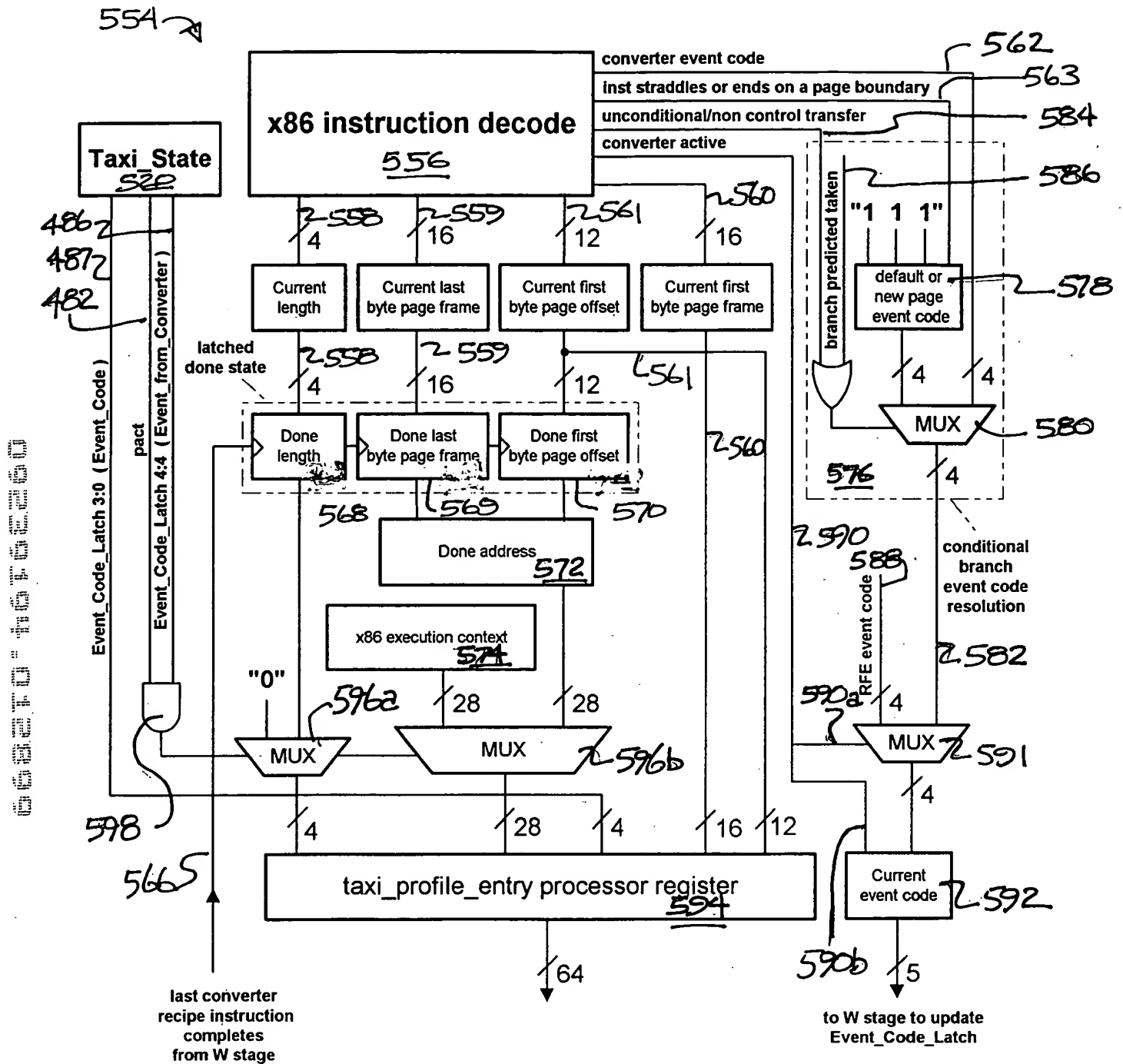


Fig. 5b